IMPACTS OF NON-CROP FARMSCAPE VEGETATION ON STRAWBERRY PEST DYNAMICS IN THE ELKHORN SLOUGH WATERSHED

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Disclaimer

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Abstract

This research project examines the impacts on key pest population dynamics of annual and native perennial non-crop hedgerows within and adjacent to commercial strawberry fields in the Monterey Bay Area. With this research we assess an alternative pest control strategy for pesticide use reduction, a topic of current urgency due to the potential both for regulatory actions limiting strawberry pest control chemicals, and for pesticide resistance development by key strawberry pests.

Project progress for the first year of funding includes grower selection; treatment and plot establishment; establishment and execution of arthropod sampling protocols; evaluation of data; and presentation of results to growers and other interested parties.

In the first year we found more lygus bugs (*Lygus hesperus*) in the annual plantings than in the strawberries, and slightly more lygus bugs in farmscaped than control fields. Two-spotted spider mites (*Tetranychus urticae*) were less abundant in strawberries close to the non-crop plants than in strawberries far from the non-crop plants, and were less abundant in the farmscaped than control fields.

This project has emphasized an integrated approach to accomplishing the multiple goals of pesticide use reduction, restoration of native vegetation, and erosion control. Grower and PCA involvement and collaboration between multiple groups (NRCS, CASFS, CAFF) have been crucial to the success of the project, helping to inform project management decisions and maximize the audience for dissemination of results.

Executive Summary

The objectives of this project are divided into two major components, the first focusing on research and the second on outreach. The objectives are as follows, organized with their associated methodologies, results, and conclusions.

Objective 1. *Determine the net effects of agricultural hedgerows, composed of mixtures of native and non-native flowering plant species, on population levels of* Lygus hesperus *Knight (Hemiptera: Miridae) (lygus bug),* Tetranychus urticae *Koch (Acari: Tetranychidae) (two spotted spider mite), and associated natural enemies within the strawberry production field; on berry damage caused by* L. hesperus, *and on pesticide use for control of lygus bugs and spider mites. Specifically, the five components of this objective are:*

i) Determine the relative abundances of L. hesperus, T. urticae, *and associated natural enemies in each hedgerow mixture.*

ii) Determine the relative impact of each hedgerow mixture on arthropod populations within the adjacent strawberry field, and the distance at which hedgerows affect these populations.

iii) Determine whether hedgerows will allow for long-term establishment of released populations of Anaphes iole *and of* Phytoseiulus persimilis *(in the second year only).*

iv) Determine the overall effect of each hedgerow mixture on pest damage to strawberry fruit; i.e. whether the benefits of increasing the natural enemy populations outweigh possible detrimental effects of increased pest habitat (in the second year only).

v) Determine the pesticide use (for lygus and spider mites) in farmscaped fields and non-farmscaped fields through grower interviews and pesticide use reports.

Strawberry growers were selected for participation in this study in the fall of 1997. Experimental strawberry plots were farmscaped with both annual and perennial hedgerow species. Hedgerow species were chosen based on (a) their theoretical value as attractors of beneficial insects and/or lygus bugs; (b) growers' perceptions of each species' appropriateness in the farmscape; and (c) native status in the area and plant community in which each farm was located (for perennials only). Annual hedgerow plants (collectively called "good bug blend," or GBB) were direct seeded into beds in early November 1997. Perennial hedgerow species were transplanted to the site in November 1997 and were hand weeded biweekly throughout the winter.

Arthropod sampling for insects and spiders was conducted by vacuum sample using a modified leaf blower (50 seconds per sample) beginning in March 1998. Samples were taken of the perennial plantings and the GBB (for part *i*, above), the strawberries within the whole farmscaped field, and the strawberry rows located 1, 5, and 20 rows away from the GBB row (part *ii* above). Samples were frozen, then arthropods were sorted and counted. Numbers were compared with values obtained from similar samples taken from control (unfarmscaped) plots.

Mite sampling was conducted weekly starting in February 1998. 40 mature, fully expanded strawberry leaves were chosen randomly from plants within the farmscaped and control plots (part *ii* above), and 10 leaves from each of rows 1, 5, and 20 away from the GBB (part *ii* above). In addition to counting spider mites (*Tetranychus urticae*), leaf samples were used to assess populations of predatory mites (most importantly *P. persimilis*), aphids, and numbers of predatory insect eggs.

Treatment effects were the most pronounced for the GBB and the strawberries within the plots. Lygus appeared earlier in the season and in greater numbers in the GBB than in either the control for the GBB or in the strawberries themselves. Degree day calculations made from these early season lygus allowed us to fairly accurately predict future nymph populations, information we have used in this second year to time lygus control methods. In addition, since early season lygus remained concentrated in the GBB rather than in the strawberries, growers have been able to concentrate control efforts in non-crop plants rather than crop plants, potentially decreasing human exposure to pesticides and overall pesticide use. Overall lygus numbers were slightly greater in the strawberries in farmscaped plots than in control plots, which points to the importance of appropriate management techniques. In the second year so far, using various management techniques, lygus numbers have been lower in farmscaped than in control plots. The GBB also affected mite populations: on many sampling dates spider mite numbers were lower in farmscaped strawberries than in control strawberries, and were lower on strawberry plants close to the GBB than on those far from it. The GBB also helped to attract generalist insect predators to the fields earlier in the season, potentially contributing to pest control.

Treatment effects were less pronounced for the perennial hedgerow, a result we expected because of the long establishment time of many of these plants. Management techniques have been modified for the second year of the study to optimize early plant growth and vigor. This, along with the increased size of the second year hedgerow plants, should increase the relative importance of the perennials to the overall pest dynamics in the second and future years of the study.

Part *iii* of Objective 1 was to be done the second year only. In the first year, *P. persimilis* were released regularly in all three sites as part of the normal pest control strategy, but we made no attempts at *P. persimilis* establishment in the non-crop vegetation. *Anaphes iole* were released once, coinciding with the peak of the first major lygus egg laying event. *A. iole* releases did not continue through the season because of lack of availability. Part *iv* (assessment of berry damage due to catfacing) was not done in 1998 due to personnel constraints, and was to be initiated the second year of funding. We are currently completing part *v* (determining pesticide use), and will submit results of post-season grower interviews as an addendum to this report.

Overall, we have found that by farmscaping in strawberries we have been able to modify pest and beneficial arthropod abundances considerably. In the current and coming years of the project we will expand the number of growers with whom we work, and will be optimizing farmscape management to provide the most pest control benefit and pesticide use reduction, while working on ways to decrease risk and costs of farmscaping for the growers.

Objective 2. *We will publicize our on-farm research findings. Three methods will be used:*
i) Grower-cooperators and their PCAs will be kept current with bi-weekly updates (written or verbal), and their concerns and observations about progress will be discussed.
ii) We will have three farm field days per year at which researchers and cooperating growers will share research findings with the public (growers, researchers, and public agencies), and discuss relevance of trials to their unique farming conditions.
iii) At the end of the study, we will publish our research findings as a brochure for farmers and in appropriate peer-reviewed and industry journals.

Throughout the growing season growers were informed about arthropod population levels in their replicate plots both during weekly arthropod sampling visits and through telephone contact. Field days were co-sponsored by the Community Alliance with Family Farmers. The first field day was held at Elkhorn Native Plant Nursery on June 24, 1998. During this field day, a graphical update of results to date was presented to cooperating growers and others in attendance. The second meeting was held in Santa Cruz on November 4, 1998, and focused on results from the organic field site, with both researchers and the grower presenting. The third field day, on November 11, 1998, was also held at Elkhorn Native Plant Nursery, and results from the Watsonville and Prunedale field sites were discussed.

We are currently in the second year of this five-year study. At the end of this year we will assess the status of the research and, if appropriate, produce our first farmer-oriented farmscape brochure. During the fifth project year we will prepare a more comprehensive brochure on farmscaping, including plant species selection, hedgerow management, and the multiple potential benefits of farmscaping. This brochure will be prepared in collaboration with the Natural Resources Conservation Service, who will emphasize erosion control benefits of farmscaping.

Body of Report

a. Introduction

Strawberries are one of the most important economic crops in the Monterey Bay region of California, with a value of nearly $300 million. Planted acreage has doubled on the Central Coast in the last fifteen years, and currently strawberries are planted on over 11,000 Central Coast acres. At the same time strawberries have the dubious distinction of using more pesticides per acre than any other crop in California (Anonymous 1996). Associated with this status, there are multiple regulatory and biological challenges which could disrupt strawberry production in the near future. Virtually all chemicals used for two-spotted spider mite (*Tetranychus urticae*) control in strawberries have been lost due either to regulatory issues or mite resistance. In addition, many of the chemicals commonly used for control of lygus bugs (*Lygus hesperus*) are listed as carcinogenic (under California's Proposition 65) or are classified by the Cal EPA as High Priority Risk materials, and all are under review due to FQPA implementation. Lygus bugs and spider mites are the two major arthropod pests of economic importance in Monterey Bay area strawberry production, and loss of chemical controls is certain to lead to increased pest damage and reduced yields.

Much of the recent strawberry acreage expansion has been on steep, highly erosive sites. The Soil Conservation Service (now the Natural Resources Conservation Service, NRCS) estimated that soil loss from some of this sloped ground can exceed 140 tons/acre in a wet year. Not only does the soil erode, but along with it comes soil adsorbed agricultural chemicals. Evidence from Elkhorn Slough, which drains into the Monterey Bay National Marine Sanctuary, shows the impacts of this erosion. Analysis of Elkhorn Slough sediments has documented multiple agricultural chemicals (Kleinfelder, Inc., 1993), most likely from prior applications on strawberries. Other wetlands and waterways in the Monterey Bay area are similarly impaired by high levels of these chemicals, including DDT, toxaphene, chlordane, endosulfan, dieldrin, endrin, and aldrin (Fleck et al., 1988; Mischke et al., 1985). As a result, there is growing pressure on strawberry growers to curb erosion from their farms, protecting wetlands and waterways of the area from further chemical and soil contamination.

In this project we have been examining a combined solution to the problems of insect and erosion control through the use of annual and perennial non-crop plantings in and around agricultural fields. Non-crop plants are being used with increasing frequency in agricultural applications to control erosion, dust, wind, pests, and as habitat for beneficial insects and wildlife. Depending on their application these plantings are called vegetative buffer strips (VBSs), windbreaks, trap crops, and/or hedgerows; use of these plantings is often called 'farmscaping'. Farmscaping with non-crop vegetation could lead to savings not only from decreased chemical purchasing and application costs, but also from decreased on-and off-farm costs resulting from erosion. However, implementation of these farmscapes would also cost growers in terms of plant establishment and maintenance. While there is increasing interest among growers, researchers, and regulatory agencies in farmscaping, little research has been done to assess or optimize interactions between different non-crop functions in agricultural systems. In the current project we have been studying the arthropod aspect of a combined solution to the problems of arthropod and erosion damage through the use of non-crop farmscape vegetation.

b. Materials and Methods

Growers for this project were selected and field plots established as part of a separate grant from the US Environmental Protection Agency's Pesticide Environmental Stewardship Program (US-EPA PESP). In November of 1997, three growers (one certified organic, two conventional) were selected for participation in the project based on their willingness and ability to give project personnel access to 2 to 10 acres of strawberries, assist in managing non-crop plantings, provide access to production records, and allow project personnel to conduct field days on their farm. A fourth grower was omitted from the study when weather conditions prevented him from early strawberry establishment. Monitoring at an additional site was initiated in September 1998, funded by the Natural Resources Conservation Service. This new grower and two others have been incorporated into the second year of our study, which is being funded through a UC-Sustainable Agriculture Research and Education Program (UC-SAREP) Biologically Integrated Farming Systems (BIFS) grant.

Experimental strawberry plots were farmscaped with both annual and perennial hedgerow species. Hedgerow species were chosen based on (a) their suspected value as attractors of beneficial insects and/or lygus bugs; (b) growers' perceptions of each species' appropriateness in the farmscape; and (c) the plant species being native to the area and appropriate to the habitat in which each farm was located (for perennials only). The annual GBB mixture was direct seeded into beds in early November 1997. Beds of GBB were spaced approximately every 50 rows of berries, in consultation with growers. For the perennial plantings, species native to the area and specific for the habitat type were chosen and transplanted from plugs and gallon containers in early December. The perennial farmscape component was located adjacent to strawberry plantings, in an unused area of the field. Annual and perennial plants were weeded biweekly by project personnel through May 1998. Cooperating growers also set up control, unfarmscaped plots for comparison with farmscaped plots. In the control plots, the control used for the GBB was the row that would have been used for planting the GBB, had the control been selected for the experimental plot. At the Wilder site, this was a bare row adjacent to the edge of the strawberry bed; at the other two sites, this was a row of strawberries at the edge of the plot. The control for the perennial plants at all sites was a weedy area adjacent to the plots which, like the GBB control, was the area which would have been planted to perennials had the control been selected for the experimental plot. See Appendix A for maps of all three sites and lists of GBB and perennial plant species used.

Arthropod sampling for insects and spiders was conducted by vacuum sample using a modified leaf blower (50 seconds per sample) beginning in March 1998. Samples were taken of the perennial plantings and the GBB (for part *i*, above), the strawberries within the whole farmscaped field, and the strawberry rows located 1, 5, and 20 rows away from the GBB row (part *ii* above). Samples were frozen, then arthropods were sorted and counted.

Mite sampling was conducted weekly starting in February 1998. 40 mature, fully expanded strawberry leaves were chosen randomly from plants within the farmscaped and control plots (part *ii* above), and 10 leaves from each of rows 1, 5, and 20 away from the GBB (part *ii* above). In addition to counting spider mites (*Tetranychus urticae*), leaf samples were used to assess populations of predatory mites (most importantly *P. persimilis*), aphids, and numbers of predatory insect eggs.

Pest and beneficial arthropod numbers in farmscaped treatments (GBB, perennial plants, and farmscaped strawberry plots) were compared with values obtained from similar samples taken from control (unfarmscaped) plots through the season by graphing values for each sampling date. In addition, since overall arthropod abundances varied considerably among the three farms, we also analyzed all arthropods in terms of their proportional abundance over the whole season in each sampling location of each field site (i.e. perennial plants, GBB, and controls for these both; the whole farmscaped and control plots; and rows 1, 5, and 20 of the farmscaped and control plots). To do this, abundances of each species were summed over the whole season in each replicate sampling location. Sums were then each converted into a fraction of the total number of that species sampled in all sampling locations at that field site over the whole season, and average values of all three treatment replicates were graphed with their standard errors. The analysis over the whole season gives a clearer picture of the effect of farmscaped treatments over the whole season, however, the data by date is also necessary, in order to show whether effects of farmscaped treatments occurred at an agronomically meaningful time in the production season.

c. Results

Vacuum samples

Because of the long establishment times of many of the perennial plants, and because of the late, cold, springtime conditions, the full benefits of natural enemy attraction of the perennial plantings were not realized in the first year. In general, there were few differences, both for pest and natural enemy species, between the perennial plants and the control for the perennials. Differences were more pronounced between the GBB and the GBB control, and between the strawberries within the farmscaped plot and strawberries within the control plot. More specific results follow.

Lygus. Lygus adults and nymphs appeared in the annual GBB earlier in the season than in the strawberries, and detection of these individuals was used in combination with the UC IPM lygus degree day model to predict the timing of the subsequent lygus generations in the strawberries. Because the 1997-98 winter was fairly warm, overwintering adult lygus may not have gone completely into diapause; because of this, we expected that we might not see distinct lygus nymph hatches this season. Figure 1a shows the average accumulated degree days, predicted first and second lygus nymph hatches, and actual lygus nymph population trends over the season for all sites. The first peak of nymphs occurs right after the predicted first hatch, and the second large peak occurs right before the predicted second hatch. These data differ somewhat when graphed site by site because of differences in degree day accumulation and lygus pressure at different locations. Figure 1b shows lygus nymph predictions and populations from just one of the three sites.

Figure 2 shows total lygus numbers in the annual GBB, compared to the control. The GBB attracted lygus early in the season, and continued to harbor more lygus than did the control throughout the season. Figure 3 shows the impact of farmscaping on the strawberries within the plots: for most dates on which lygus were found in the strawberries, their numbers were higher in the farmscaped than in the control plots. Figures 4, 5, and 6 show lygus numbers in strawberry rows 1, 5, and 20 from the GBB mixture, and compare these numbers with those in the control plot. While values are higher in the farmscaped plots in all three figures, the total numbers as well as the difference between the farmscaped and control plots decrease as one gets further from the GBB. Figure 7, the relative distribution of lygus over the whole season in all sampling locations, shows the degree to which lygus preferred the GBB over all other locations. In addition, Figure 7 illustrates lygus spillover from the GBB into the adjacent strawberry plot, particularly row 1.

Natural enemies. The majority of generalist predators collected in vacuum samples were spiders, lady beetles, green and brown lacewings (*Chrysoperla*, *Chrysopa*, and *Hemerobius* spp.), damsel bugs (*Nabis* spp.), bigeyed bugs (*Geocoris* spp.), and minute pirate bugs (*Orius* spp.). All of these except the spiders were analyzed together, in a sample called "generalist predators.". Spiders were analyzed separately because it is not clear whether they contribute to strawberry pest control to the same degree as do the other predators. Generalist predator numbers built up slightly earlier in the GBB than the control, and were more abundant in the GBB on many sampling dates (Figure 8). A graph of the relative distribution of generalist predators over the whole season (Figure 9) shows an overall slight habitat preference for the GBB, coupled with a slight increase in generalist predators in the farmscaped berries as a whole. Juvenile generalist predators show more distinct habitat preference for the GBB over its control (Figure 10); this preference spilled over to the first row of strawberries, but not to the farmscaped strawberry field as a whole. Spiders were considerably more abundant in the perennial hedgerows than in the control, and were more abundant on some dates in the farmscaped plots than the control plots (Figures 11 and 12). The overall effect of these differences on relative abundances over the whole season is shown in Figure 13; this figure also shows that spiders did not prefer the GBB over either its control or the strawberries within the plots. Hymenoptera were consistently more abundant in the GBB than in the control (Figure 14); this difference was not apparent in the strawberries (Figure 15). Over the whole season, the strong preference of hymenoptera for the GBB may have led to a slight increase in hymenoptera abundance in the first strawberry row (Figure 16).

Leaf samples

Mites. Figure 17 shows the percent of strawberry leaflets with mites in strawberry rows 1, 5, and 20 away from the GBB. Through mid-June, fewer strawberry leaflets in row 1 appear to have harbored spider mites than strawberries in either row 5 or row 20. The row differences in percent mite infestation were not apparent in the control treatment (Figure 18); in the control, percent mite infestation levels did not differ between rows 1, 5, and 20. These early season treatment differences did not correspond to an early season drop in percent mite infestation in the whole plot (Figure 19). Percent mite infestation in the whole plot samples peaked at a higher level in farmscaped than control fields, after which control plot values were higher than farmscaped plot values for the rest of the season. However, when summed over the whole season, the farmscaped plots had fewer mites than did control plots, as did the first row of farmscaped berries (Figure 20).

When mites were analyzed in terms of average number of mites per leaflet, results differ from percent mite infestation results in two ways. First, there was not as pronounced a late-season difference in mites per leaflet between treatments in the whole field samples (Figure 21), and second, the average number of mites per leaflet increased in rows further into the field (i.e. row 1 < row 5 < row 20) in both the farmscaped and the control fields (Figures 22 and 23). Furthermore, peak treatment differences in mites per leaflet were more pronounced than were peak percent mite infestation differences, as can be seen by comparing values in Figures 22 and 23.

Aphids. When summed over the whole season, aphids were relatively less abundant in farmscaped berries than in control plots (Figure 24). In the row data, aphids on leaflets in the fifth strawberry row of farmscaped plots were less abundant than in the control plot; values for rows 5 and 20 did not differ by treatment.

Natural enemies. The most common spider mite natural enemies in leaf samples were the predatory mites *P. persimilis* and *Amblyseius californicus*, and green and brown lacewings. Figure 25 shows the number of these natural enemies on strawberry leaves in rows 1,5, and 20 away from the GBB. Natural enemy numbers built up earliest in the season in row 20, furthest from the GBB. Percent leaflets with natural enemies in the whole field sample peaked in the farmscaped plot at almost double the value of the control plot (Figure 26). The peak percentage of leaflets which contained both mite colonies and natural enemies was higher in the farmscaped than control plots, as well (Figure 27). However, there was no treatment effect on natural enemies in the whole field through the whole season (Figure 28), and the relative proportion of leaflets with both mite colonies and natural enemies was somewhat lower in farmscaped than control plots over the whole season (Figure 29). In addition, the measures of both natural enemies per leaflet and mite colonies with natural enemies were lower in rows 1 and 5 in farmscaped than in control plots (Figures 28 and 29).

d. Discussion

Vacuum samples

Overall, lygus obtained through vacuum sampling were slightly more abundant in the strawberries in farmscaped plots than in control plots, and the majority of lygus bugs in the farmscaped plots were relatively near to the GBB. These results indicate both the potential to use a plant attractive to lygus to concentrate the insects away from crop plants, and the need for appropriate management once the insects are concentrated. Such management techniques could include pesticide application, use of biocontrol agents, field-scale vacuuming, or mowing and removal of plant material. By timing the use of these management tools to coincide with the development of the lygus bug population the usefulness of non-crop vegetation as a pest control device can be maximized.

The timing of the aforementioned procedures can be based upon degree day calculations. We found that degree day calculations made from early season lygus allowed us to fairly accurately predict future nymph populations and thus to gauge when pest management techniques could be most efficiently used. Degree day predictions are most useful in years and insect species with a distinct diapause. The 1997-1998 winter was relatively warm, causing in a fairly soft diapause for lygus. As a result, peaks in lygus populations were less distinct than they would be in a year with a cold winter and hard lygus diapause. In years of colder winters, a good bug blend or single plant species attractive to lygus could be of value in biofixing and predicting future lygus generations in berries. Because the non-crop vegetation is preferred by lygus, the first adults to emerge from diapause will appear in the good bug blend in higher numbers and earlier than they will appear in berries. These adults can be used to predict the timing of the next hatch, which contains the first lygus for which most farmers spray.

In addition to attracting lygus bugs, the GBB helped to attract more generalist insect predators to the field edges than did the control. In theory, once attracted to field edges with non-crop vegetation, beneficial insects should not only move into fields and work to control pests there, but also control pests that are in the non-crop vegetation itself. We found the potential for both actions in this study: there was a slight increase over the whole season in generalist predators in farmscaped compared to control fields, and there were also high concentrations of both pest and beneficial species in the GBB itself. In several ways it is advantageous to focus beneficial insects in non-crop vegetation rather than in the crop. First, by controlling pest species within the non-crop vegetation, beneficial insects may prevent pest species from even reaching the crop area. Second, a non-crop area is an ideal place for beneficial species since it may be maintained in ways which cause less disruption to beneficial insects than occurs in the production field, and thus can serve as an insectary . In our study, juvenile generalist predators were more likely to be found in the GBB during the production season than in any other habitat, indicating that the GBB did serve this insectary function. Another indication of the insectary function was that generalist predators remained numerous through mid-November in one perennial hedgerow which we sampled through the winter. Predators built up earlier in this hedgerow than in the control in the following spring, presumably at least partly because of overwintering populations. It is important to keep this insectary function in mind when deciding on lygus management methodologies and timing within non-crop vegetation. Rather than thinking about non-crop vegetation as only a trap crop or only an insectary, it may be useful to consider the ratio of natural enemies to lygus prior to applying any management technique.

Leaf samples

In addition to attracting lygus bugs, the GBB also affected mite populations: on many sampling dates the percent of leaflets with spider mites was lower in farmscaped strawberries than in control strawberries, and was lower on strawberry plants close to the GBB than on those far from it. However, while farmscaped plots had a lower percent of leaflets with mites than control plots, both treatments had about the same average number of mites per leaflet. In other words, mite distribution was patchier in farmscaped plots than in control plots. A likely reason for this is that mite movement was slowed in farmscaped plots due to some protection from wind afforded by the GBB.

Natural enemies of spider mites did not seem to be responsible for decreasing mite numbers in farmscaped plots any more than in control plots. Over the whole season, there were actually fewer spider mite natural enemies, and a lower percentage of mite colonies with natural enemies, in farmscaped than in control plots. Natural enemies seemed to be primarily acting in a density-dependent manner to varying concentrations of prey, regardless of experimental treatment: throughout the season, peaks in the graphs of percent mite colonies with natural enemies followed peaks in the corresponding graphs showing mite infestation levels.

Results from this first year have helped inform the project in this second year in several ways. First, we have managed the non-crop plants much more intensively this year for growth and vigor, heavily mulching the perennial plantings and putting annuals and perennials on drip irrigation early in the season. This should improve plant attractiveness to insects throughout the season. Secondly, we have changed the focus of annual plantings from a beneficial insect and lygus attractor, to a lygus trap crop primarily, by modifying the species composition of the plant mixture. The species used in the annual plantings for 1998 (called "good bug blend," or GBB) and 1999 (called "trap crop") are listed in Appendix A. In 1999 we retained only the three main lygus attractors, alfalfa, mustard, and alyssum, and left all other plants out of the mix. In addition, we have refined our use of this trap crop in lygus management. In the spring, when lygus move in from surrounding vegetation, they go into the trap crop before they move into the strawberries. We use these early lygus counts to predict future population flushes and lygus appearance in strawberries, using a degree day model. We then use these predictions to time trap crop mowings and to inform growers of potential lygus peaks so they can time pesticide applications. In the second year so far, using these management techniques, lygus numbers have been lower in some farmscaped plots than in their control plots. In addition, since early season lygus remained concentrated in the GBB rather than in the strawberries, in the second year so far growers have been able to concentrate control efforts in non-crop plants rather than crop plants, potentially decreasing human exposure to pesticides and overall pesticide use.

It remains to be seen whether the farmscaping modifications we have made have made a significant impact on pesticide use. We are currently conducting post-harvest interviews with growers, and will submit results of post-season grower interviews as an addendum to this report.

e. <u>Summary and Conclusions</u>

This research project examines the impacts on key pest population dynamics of annual and native perennial non-crop hedgerows within and adjacent to commercial strawberry fields within the Monterey Bay Area. With this research we assess an alternative pest control strategy for pesticide use reduction, a topic of current urgency due to the potential both for regulatory actions limiting strawberry pest control chemicals, and for development of pesticide resistances by key strawberry pests. In the first year of funding we have selected grower cooperators, established treatments and plots, established and executed arthropod sampling protocols, and presented results to growers and other interested parties.

Overall, we have found that the effects of farmscaping in strawberries vary considerably from species to species. Lygus appeared to differentiate strongly between habitat types in this study, with populations in general appearing earlier in the season and in greater numbers in the GBB than in either the control for the GBB or in the strawberries themselves. Parasitic hymenoptera also strongly preferred the GBB over the control or strawberries. None of the other insects showed as strong a preference for one particular habitat type, but all showed some degree of preference. Generalist predators were slightly more abundant over the whole season in the GBB than in the control; juvenile generalist predators were more abundant in the GBB than in other habitats; spiders were more abundant in the perennial plantings than in the control; and aphids were slightly more abundant in control than farmscaped plots. Spider mites, as mentioned above, differed in distribution between the two treatments, appearing patchier in farmscaped than in control plots.

These results point to the importance of both tailoring non-crop vegetation to specific arthropod species, and managing the vegetation appropriately for those species. For example, our results indicate that an annual planting of alfalfa and brassicas is effective at attracting lygus bugs, but that managing the planting - e.g. with mowing, releases of beneficial insects, or insecticides - is critical to prevent the lygus from then going into the crop field. Our results also indicate that a technique such as mowing might be more appropriate to use in the GBB than insecticides, because of the large number of juvenile generalist predators in the vegetation. The preference of parasitic wasps for the GBB indicate that the GBB might be a good place for parasitoid releases for lygus control, as well.

In the current and coming years of the project we will expand the number of growers with whom we work in order to better assess results of farmscaping. We will also be optimizing farmscape management to provide the most pest control benefit and pesticide use reduction, while working on ways to decrease risk and costs of farmscaping for the growers.

References

ABA Consultants. 1988. Elkhorn Slough Wetlands Management Plan. Prepared for Monterey County and the California Coastal Conservancy. Capitola, CA. 144 pp.

Anonymous. 1996. 1995 Annual pesticide use report. California Department of Pesticide Regulation, Sacramento, CA.

Division of Agriculture and Natural Sciences (DANR). 1993. Integrated Pest Management for Strawberries. University of California Statewide IPM Project, Davis.

Klienfelder, Inc. 1993. Elkhorn Slough 205(j) Uplands Water Quality Management Plan. Prepared for the Association of Monterey Bay Area Governments (AMBAG).

Mischke, T., K. Brunetti, V. Acosta, D. Weaver, and M. Brown. 1985. Agricultural Sources of DDT Residues in California's Environment. California Department of Food and Agriculture, Environmental Hazards Assessment Program, Sacramento.

Office of Pesticide Programs (OPP). 1997. List of Chemicals Evaluated for Carcinogenic Potential. US Environmental Protection Agency, Washington, DC.

Soil Conservation Service. 1984. Strawberry Hills target area. Watershed area study technical report, Monterey County, CA. USDA-SCS, Davis, CA. 235 pp.

Welch, N.C. 1997. Strawberry Sample Costs 1996: Santa Cruz and Monterey Counties. University of California Cooperative Extension.

Appendix A

Field site maps and plant species used for GBB and perennial plantings

Plant species used in good bug blend (GBB) in 1998:

red radish, coriander, dill, nasturtium, baby's breath, celery, caraway, chervil, carrot, parsley, yarrow, white sweet alyssum, semi- and non- dormant alfalfa

The radish dominated the mixture in the early part of the season (through May, making up about 80% of the cover), after which the alfalfas dominated (about 90% of the cover).

Plant species used in trap crop in 1999:

daikon radish, radish "cherry bell," semi- and non- dormant alfalfa, sweet alyssum

Plant species used in native perennial plantings in 1998 and 1999:

Coastal Scrub habitat:

- Yarrow (*Achillea millefolium*)
- California sagebrush (*Artemesia californica*)
- Coast buckwheat (*Eriogonum latifolium*)
- Seaside daisy (*Erigeron glaucus*)
- Lizard tail (*Eriophyllum staechadifolium*)
- Gum plant (*Grindelia stricta*)
- Seaside aster (*Lessingia californica)*
- Coffeeberry (*Rhamnus californica*)

Coastal Prairie habitat:

- Yarrow (*Achillea millefolium*)
- California sagebrush (*Artemesia californica*)
- Monterey ceanothus (*C. cuneatus* var. *rigidus*)
- Catherine's lace (*Eriogonum giganteum*)
- Coast buckwheat (*E. latifolium*)
- Lizard tail (*Eriophyllum staechadifolium*)
- Gum plant (*Grindelia stricta*)
- Coffeeberry (*Rhamnus californica*)

Oak Woodland habitat:

- Yarrow (*Achillea millefolium*)
- California sagebrush (*Artemesia californica*)
- Monterey ceanothus (*Ceanothus cuneatus* var. *rigidus*)
- 'Blue Blossom' ceanothus (*C. thrysifloris)*
- Catherine's lace (*E. giganteum*)
- Coast buckwheat (*Eriogonum latifolium*)
- Coffeeberry (*Rhamnus californica*)
- Blue elderberry (*Sambucus mexicana*)

Appendix B

Figures and tables

Figure 1a. Average accumulated degree days for lygus at all sites. Predicted dates of first and second hatches, based on presence of first adult in GBB, are indicated on the graph. Lygus nymphs are summed values from GBB and whole farmscaped strawberry field.

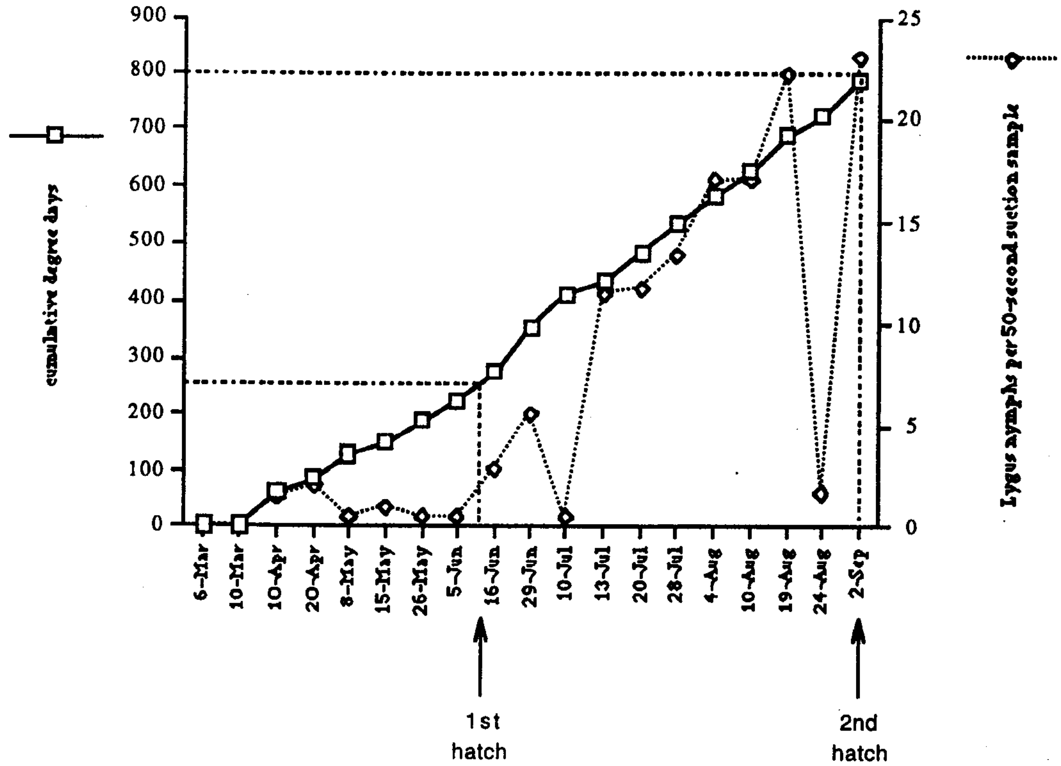


Figure 1b. Accumulated degree days for lygus at north coast field site. Predicted date of first hatch, based on presence of first adult in GBB, is indicated on graph. A second hatch. predicted at 1051 DD, did not occur in 1998. Lygus nymphs are summed values from GBB and whole strawberry field.

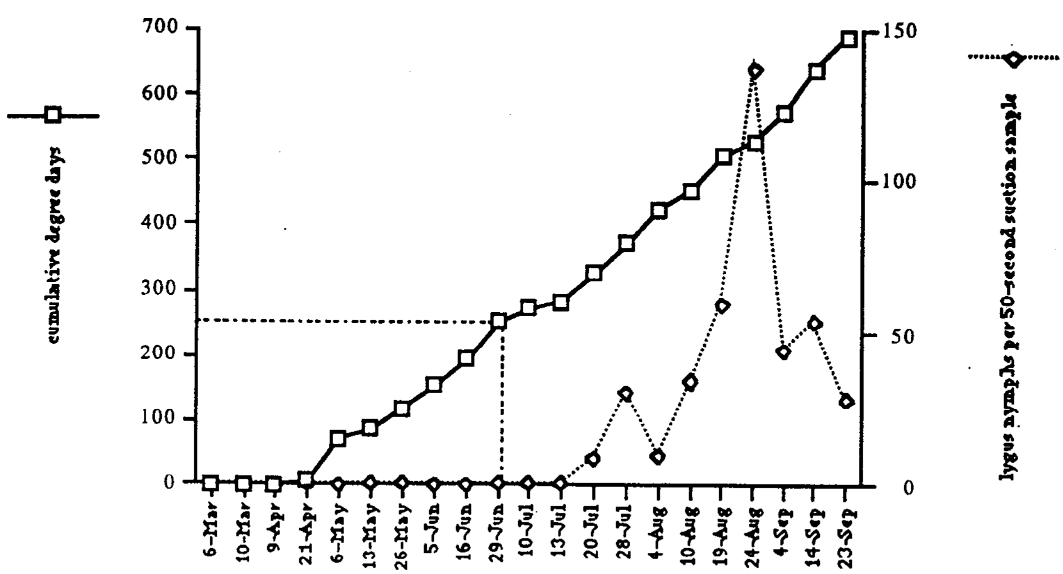


Figure 2. Average total lygus in annual GBB (good bug blend)

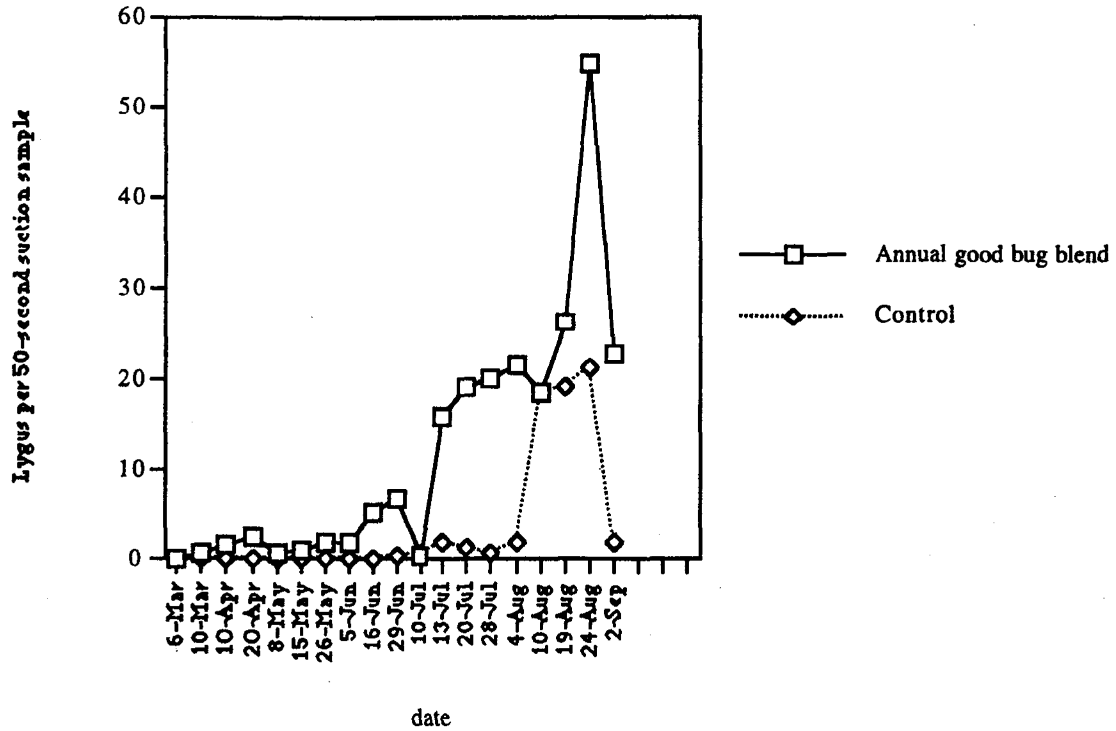


Figure 3. Average number of total lygus in farmscaped vs. control berries

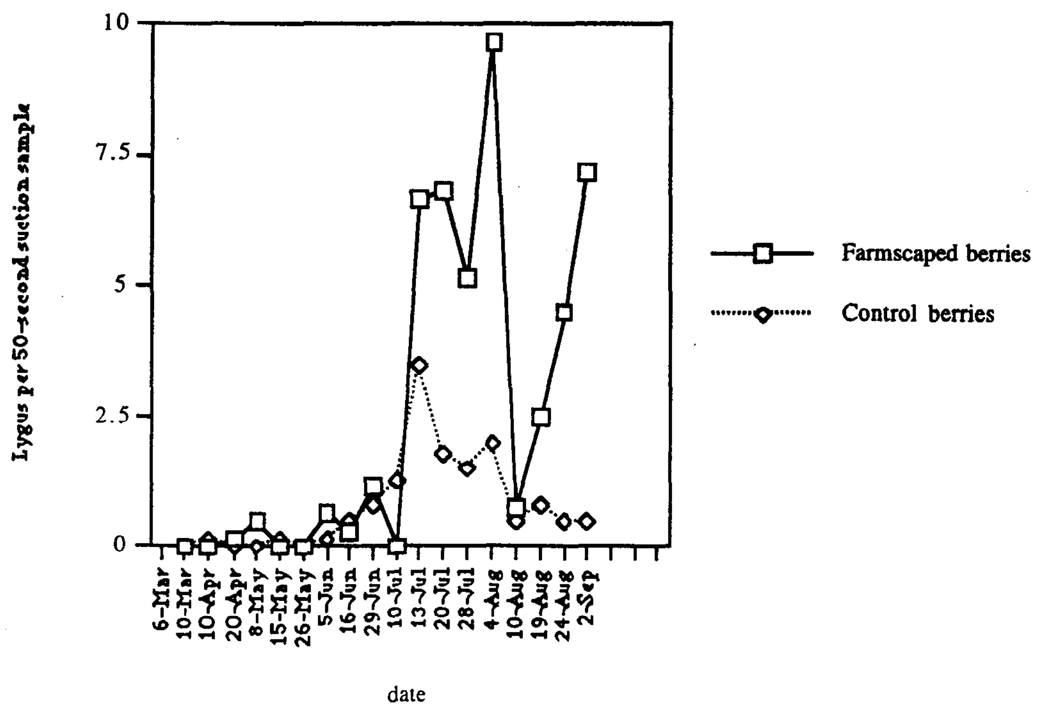


Figure 4. Average total lygus in first row of berries adjacent to GBB vs. control

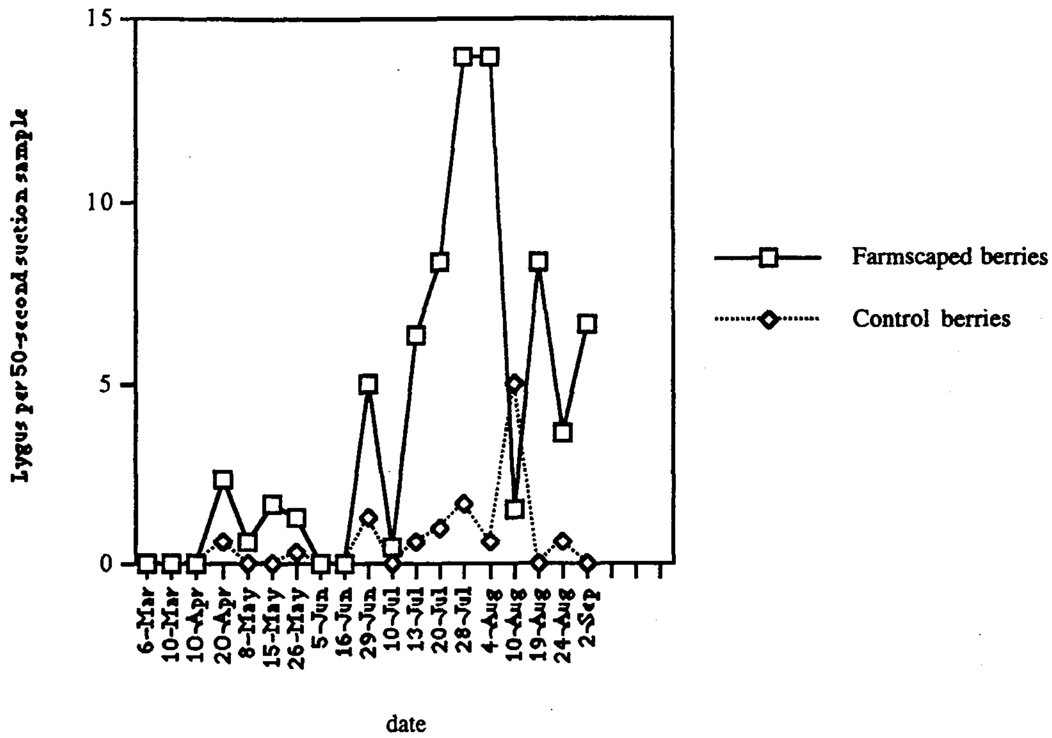


Figure 5. Average total lygus in fifth row of berries from GBB vs. control

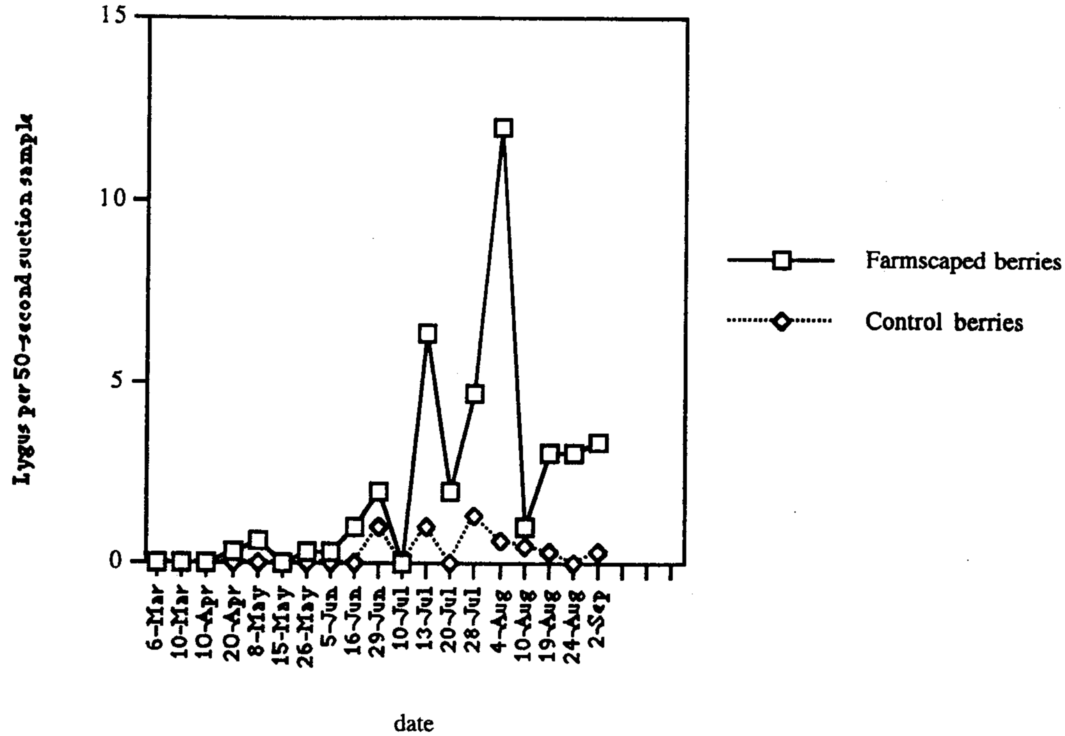


Figure 6. Average total lygus in 20th row of berries from GBB vs. control

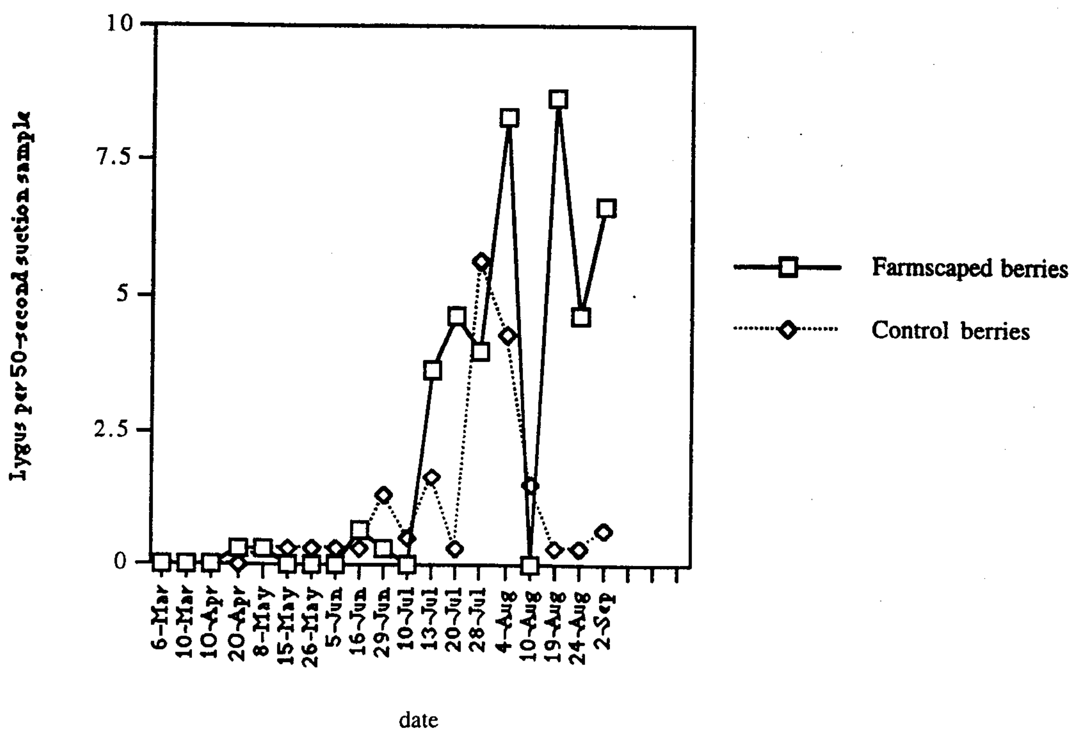


Figure 7. Relative distribution of total lygus in suction samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

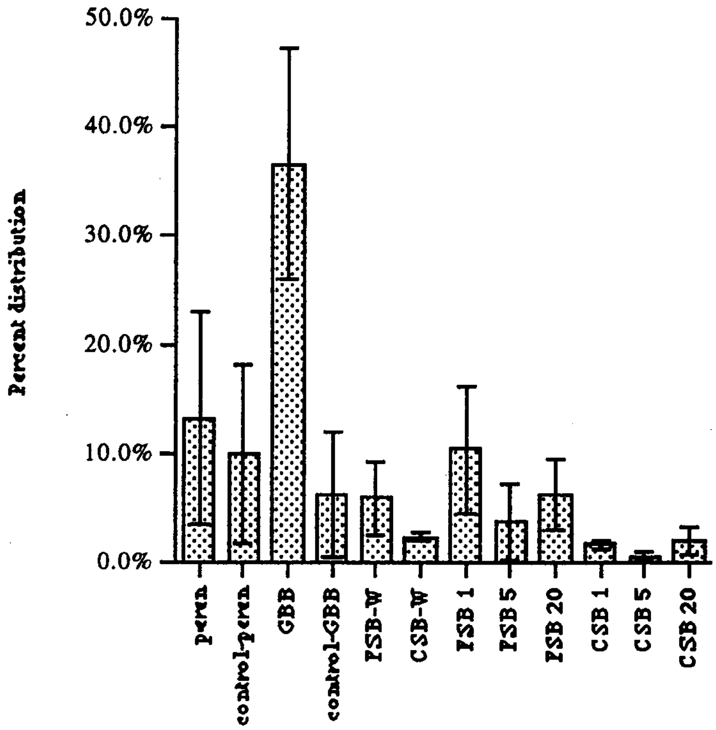


Figure 8. Average number of generalist predators in annual good bug blend (GBB)

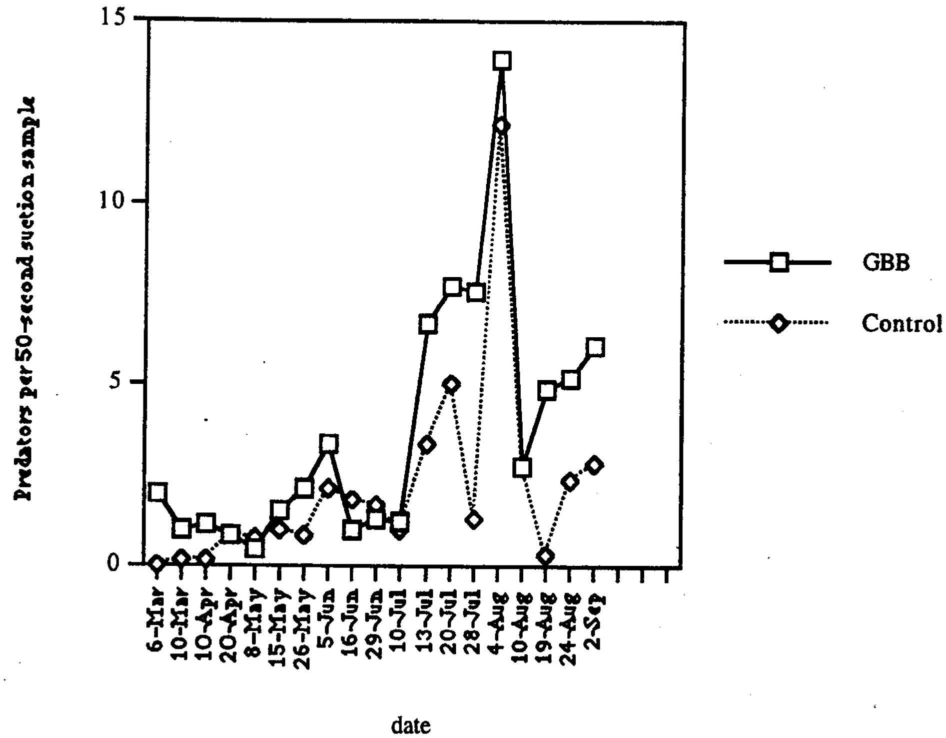


Figure 9. Relative distribution of generalist predators in suction samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

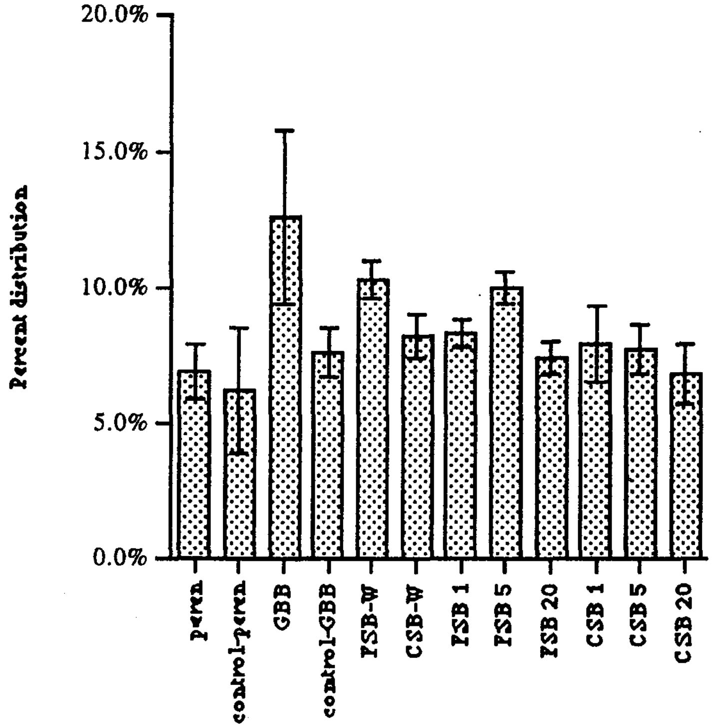


Figure 10. Relative distribution of juvenile generalist predators in suction samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

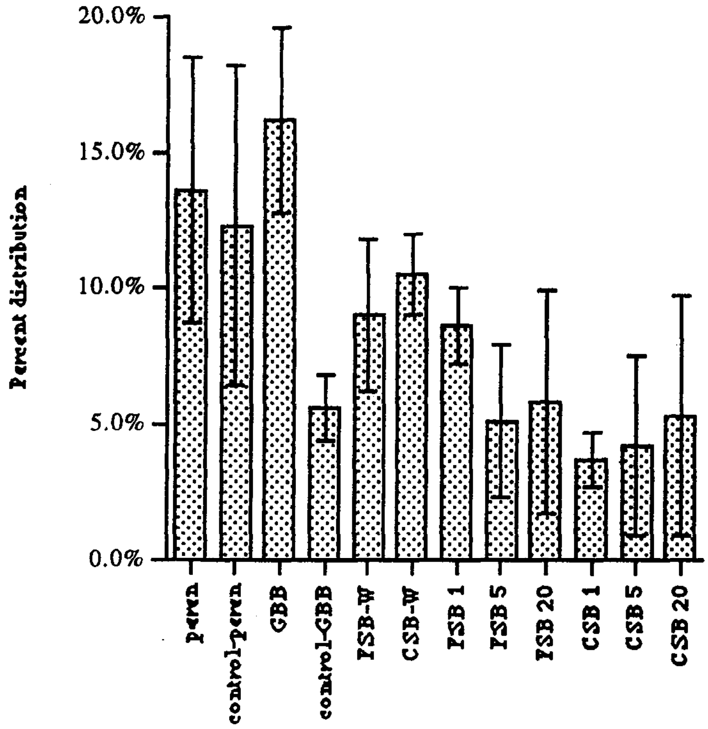


Figure 11. Average number of spiders in perennial hedgerow vs. control

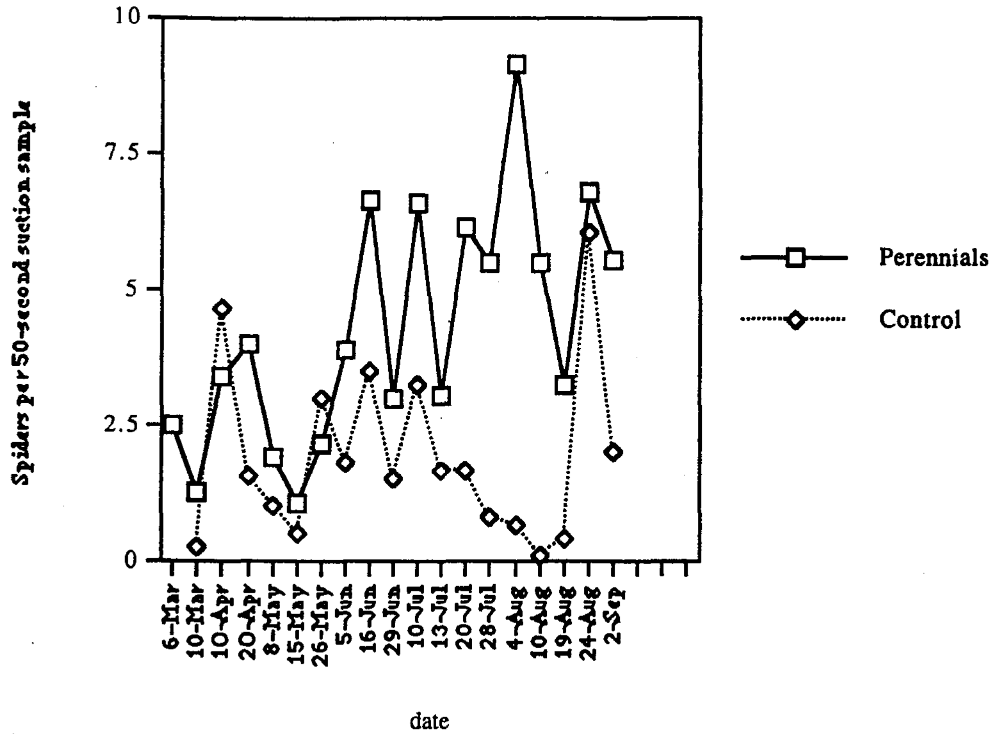


Figure 12. Average number of spiders in farmscaped vs. control strawberries

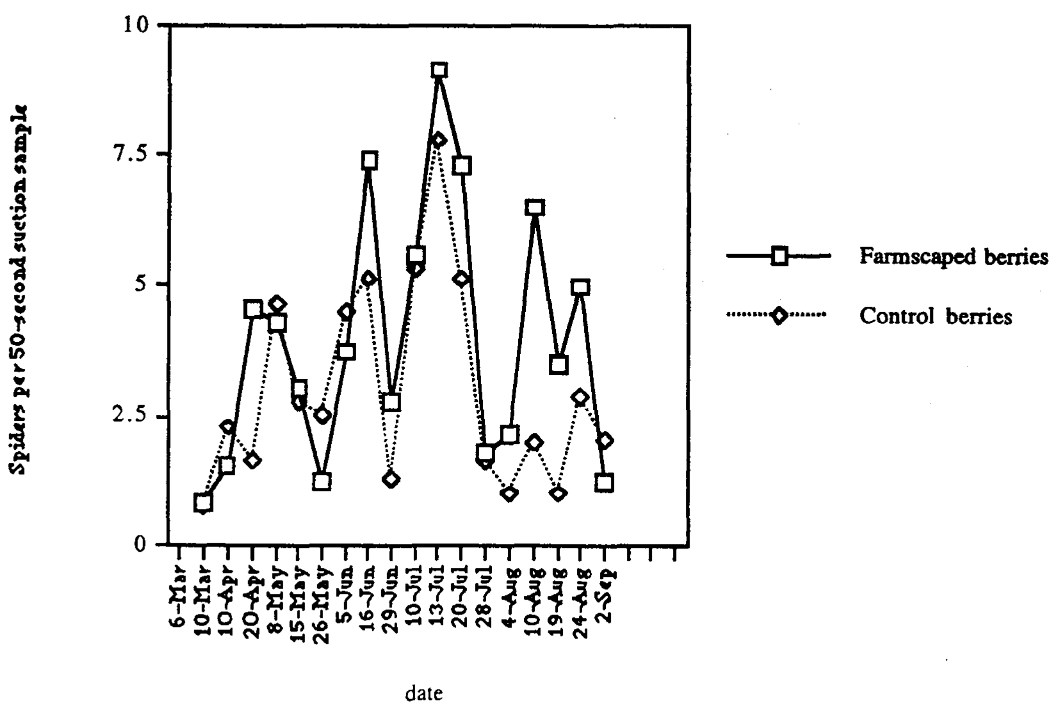


Figure 13. Reative distribution of spiders in suction samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

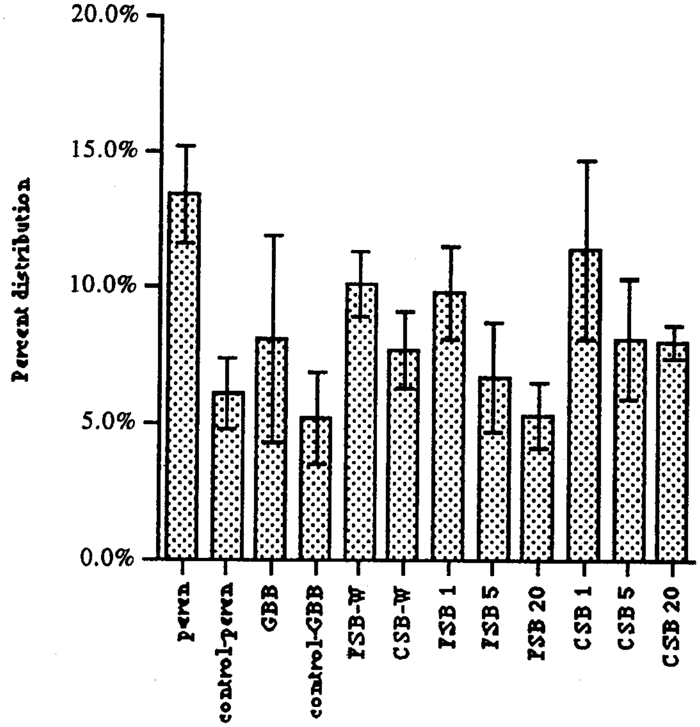


Figure 14. Average number of parasitic hymenoptera in annual good bug blend (GBB)

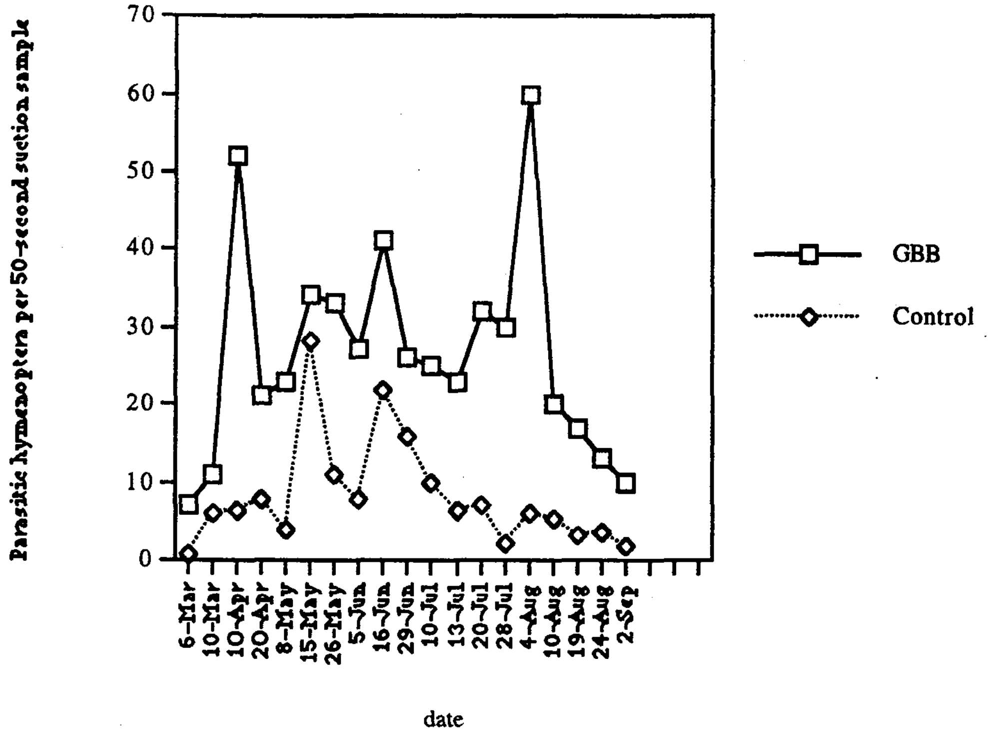


Figure 15. Average number of parasitic hymenoptera in farmscaped vs. control strawberries

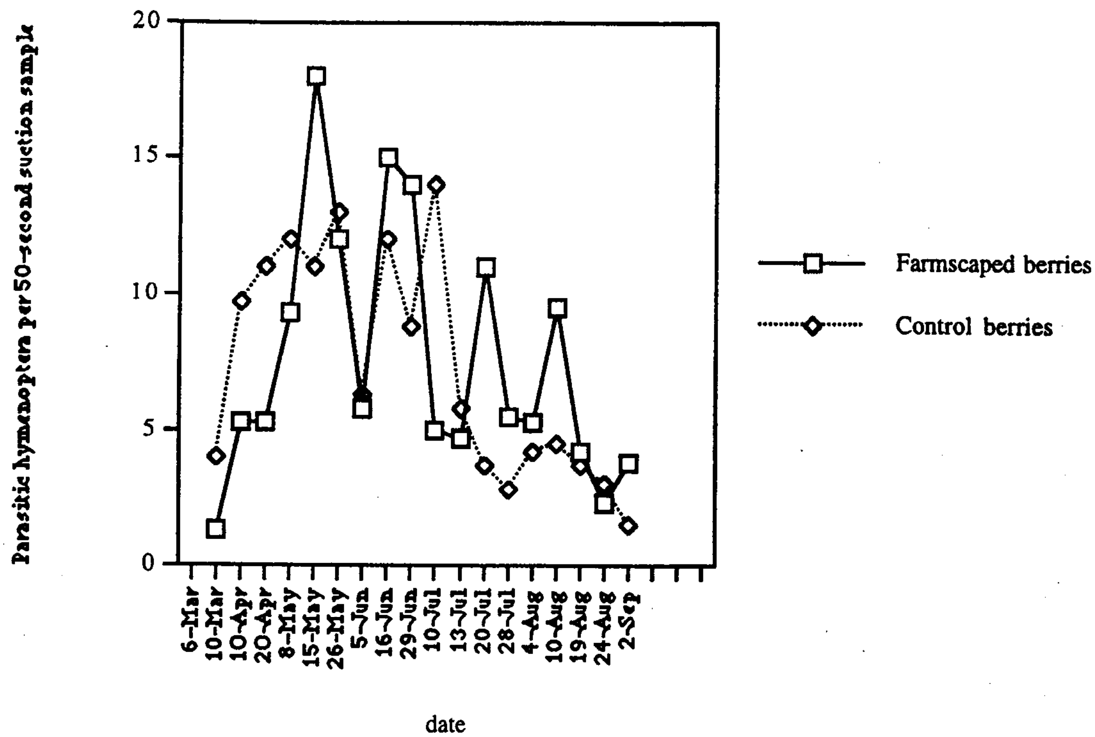


Figure 16. Relative distribution of parasitic wasps in suction samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

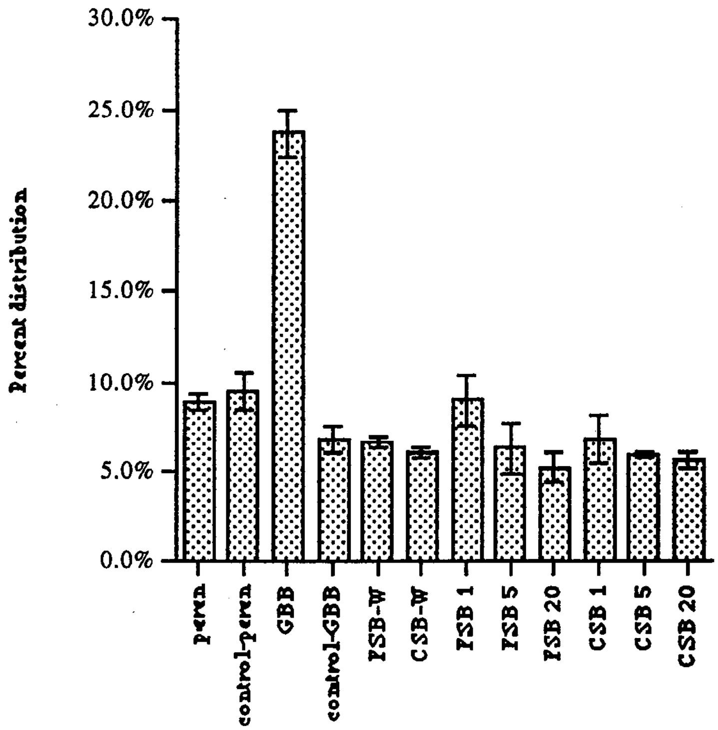


Figure 17. Average percent of leaflets with mites in farmscaped strawberry rows 1, 5, and 20 away from GBB

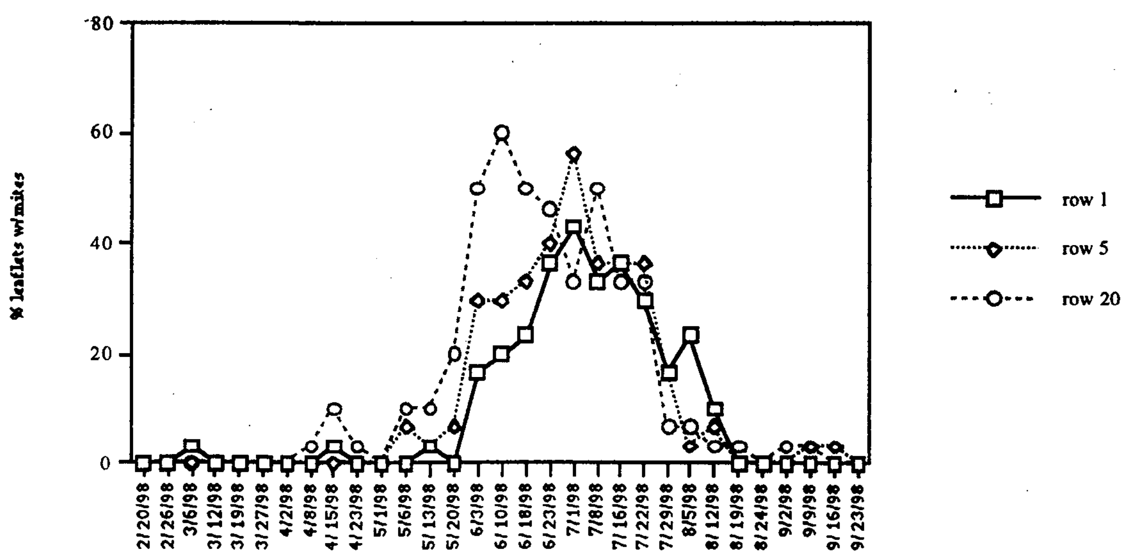


Figure 18. Average percent of leaflets with mites in control strawberry rows 1, 5, and 20 from edge of plot

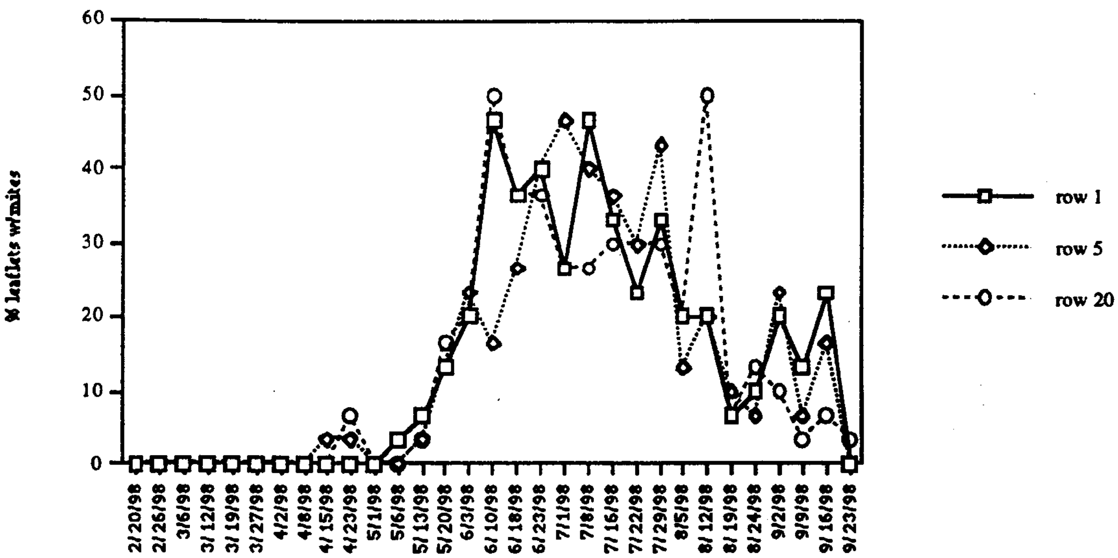


Figure 19. Average percent of leaflets with mites in farmscaped vs. control strawberry plots

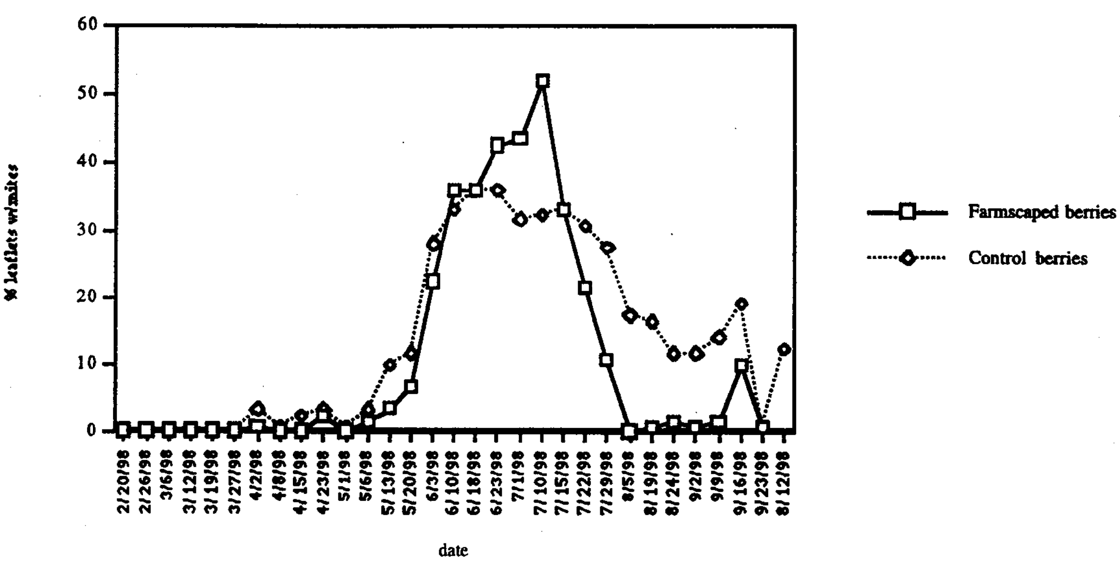


Figure 20. Relative distribution of percent of leaflets with mites in leaf samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

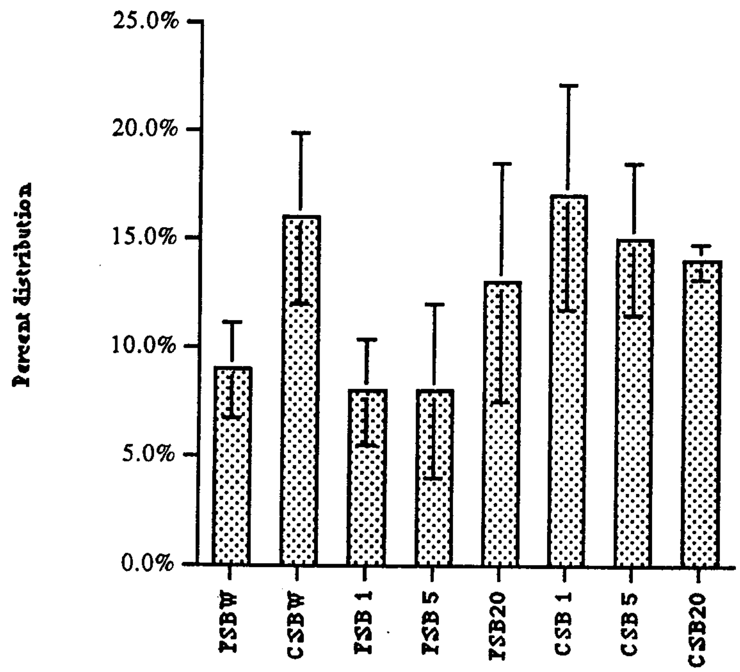


Figure 21. Average number of mites (adults + nymphs) per leaflet in farmscaped vs. control strawberry plots

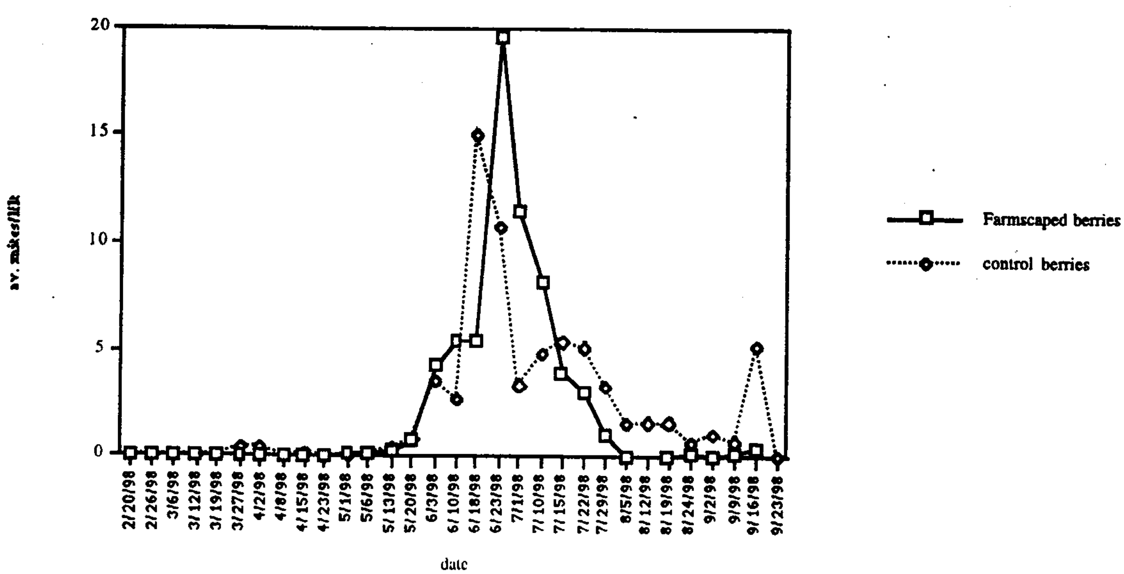


Figure 22. Average number of mites (adults + nymphs) per leaflet in rows 1, 5, and 20 away from GBB in farmscaped plots

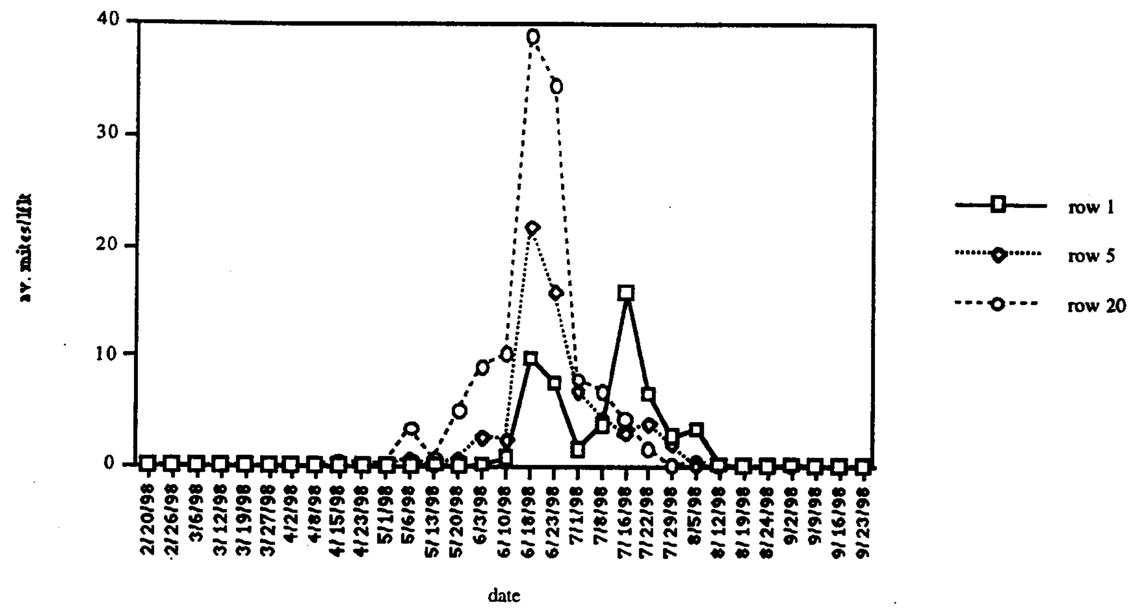


Figure 23. Average number of mites (adults + nymphs) per leaflet in control plots, rows 1, 5, and 20 away from plot edges

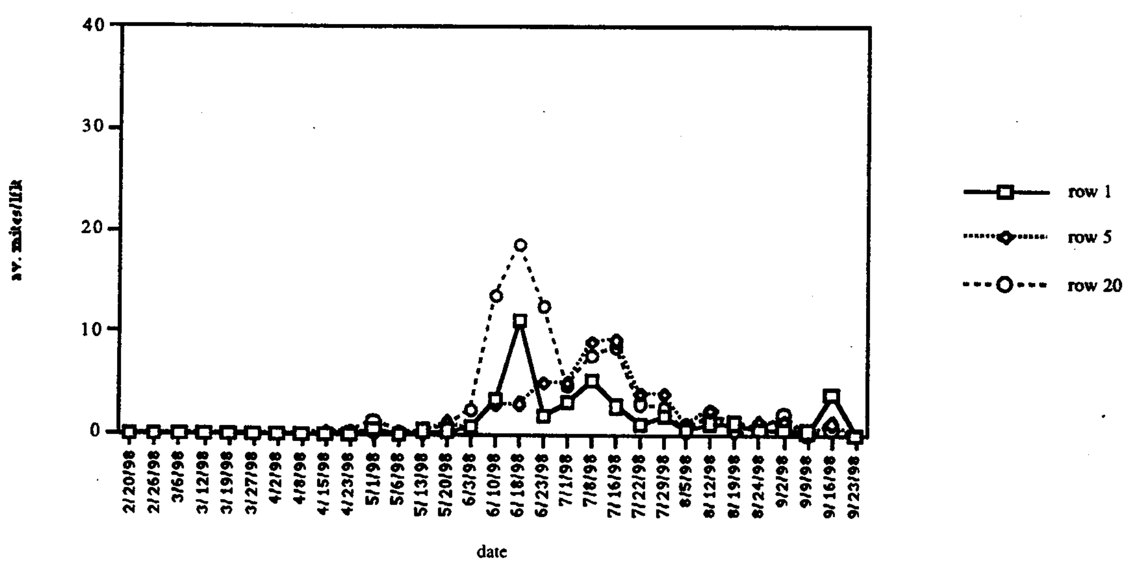


Figure 24. Relative distribution of aphids per leaflet in leaf samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

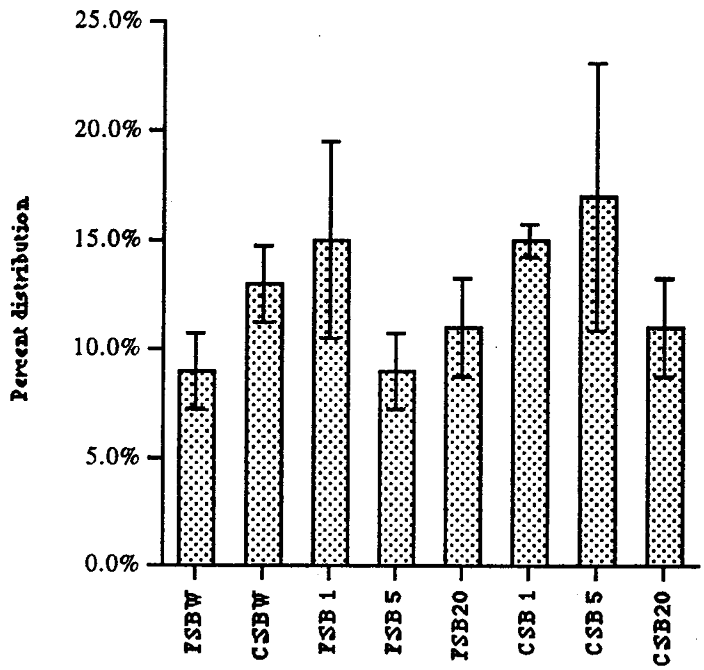


Figure 25. Average percent of leaflets with mite natural enemies in rows 1, 5, and 20 away from GBB in farmscaped plots

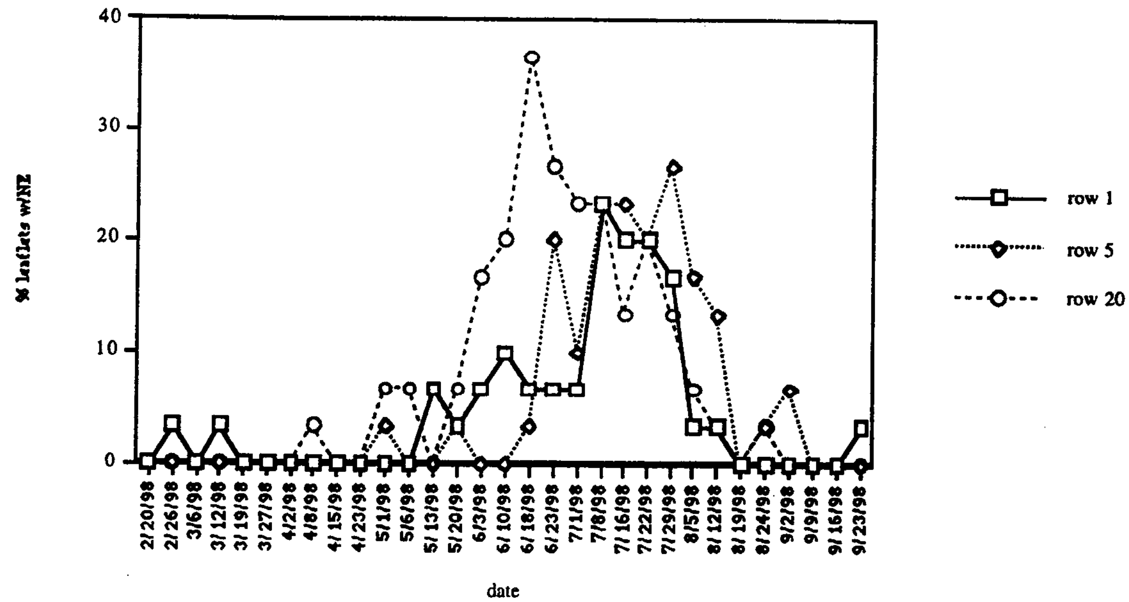


Figure 26. Average percent of leaflets with natural enemies in farmscaped vs. control strawberries

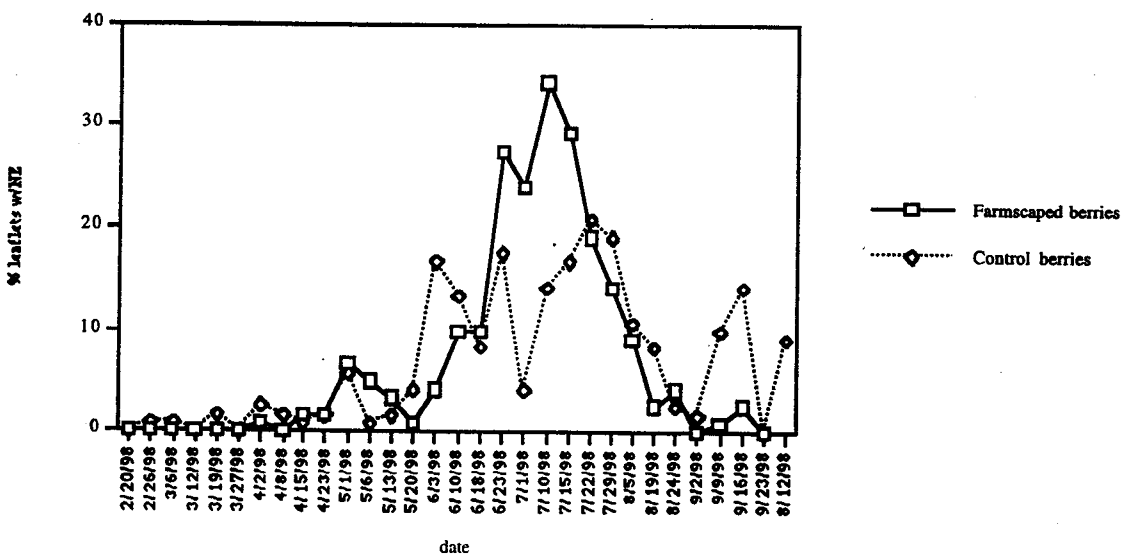


Figure 27. Average percent of mite colonies with natural enemies in farmscaped vs. control strawberries

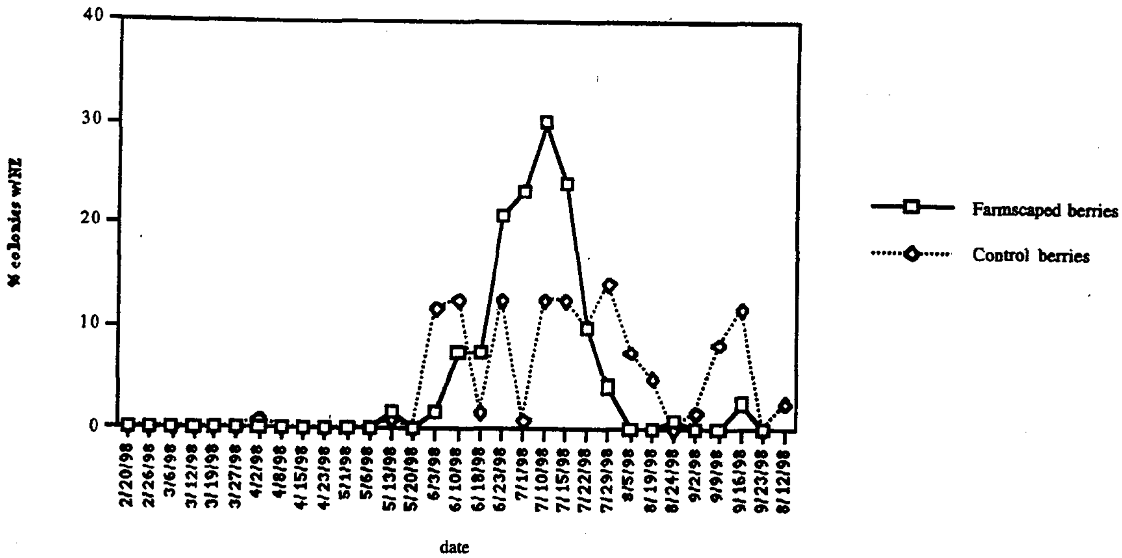


Figure 28. Relative distribution of # natural enemies per leaflet in leaf samples in all sampling locations over whole season

Averages ± 1 S.E.M. "Peren" = perennial hedgerow; "control-peren" = control for perennial hedgerow; "GBB" = annual good bug blend; "control-GBB" = control for GBB; "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.

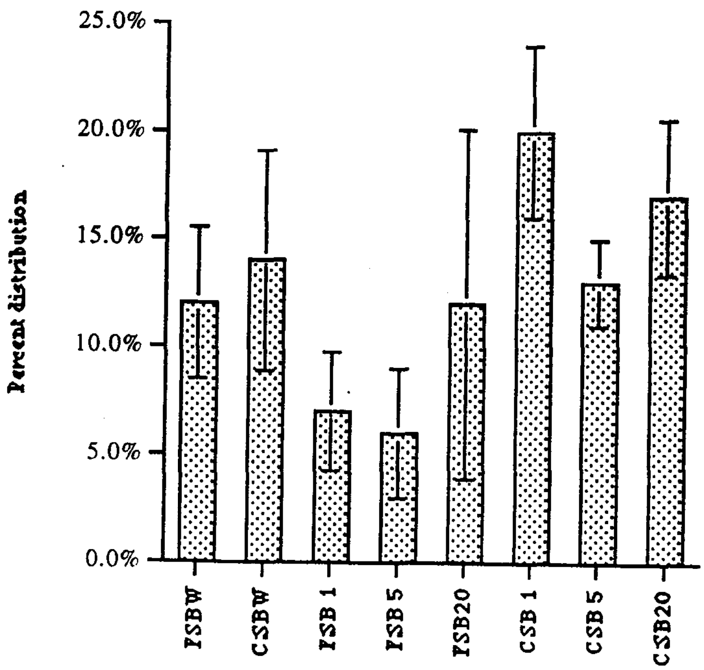
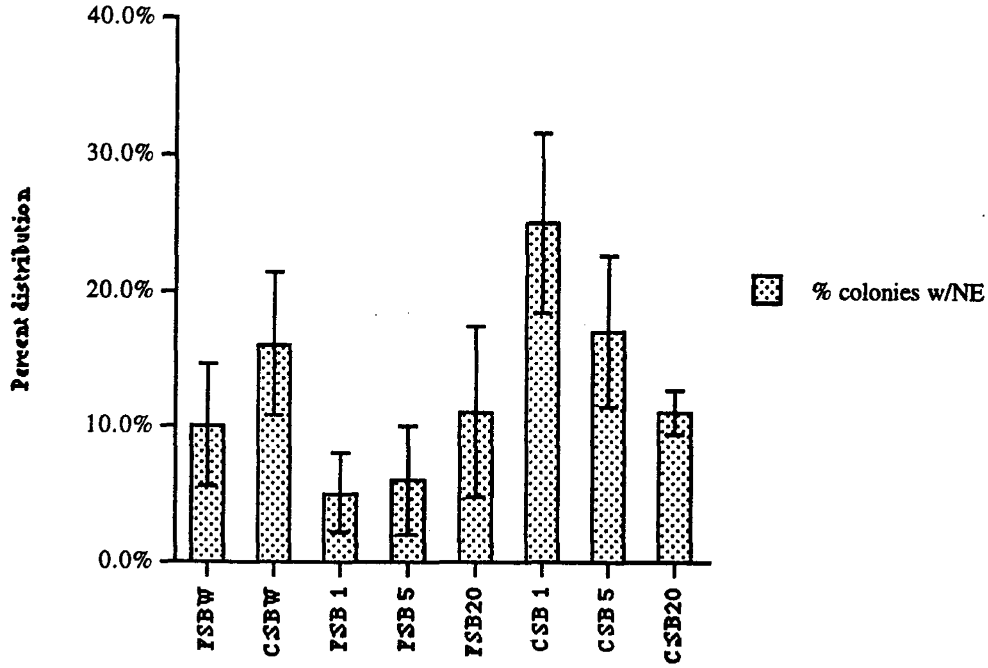
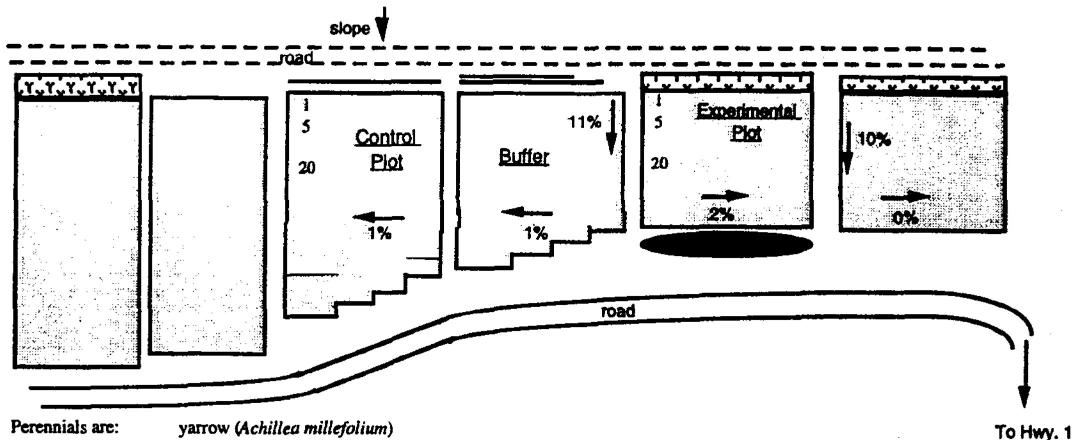


Figure 29. Relative distribution of % mite colonies with natural enemies in leaf samples in all sampling locations over whole season

Averages ± 1 S.E.M. "FSBW" = farmscaped strawberry plot: whole field; "CSBW" = control strawberry plot: whole field; FSB 1, 5, and 20 and CSB 1, 5, and 20 = rows 1, 5, and 20 of farmscaped (FSB) or control (CSB) fields. Center to center strawberry row width is about 4 ft.



Strawberry Farmscaping Project
Site Design : Coastal Scrub Habitat



Perennials are: yarrow (*Achillea millefolium*)
coast buckwheat (*Eriogonum latifolium*)
California aster (*Lessingia silaginifolia*)
Seaside daisy (*Erigeron glaucus*)
Gum plant (*Grindelia stricta*)
Lizard tail (*Eriophyllum staechadifolium*)
Coffeeberry (*Rhamnus californica*)
California sagebrush (*Artemesia californica*)

= bare rows (no good bug blend)

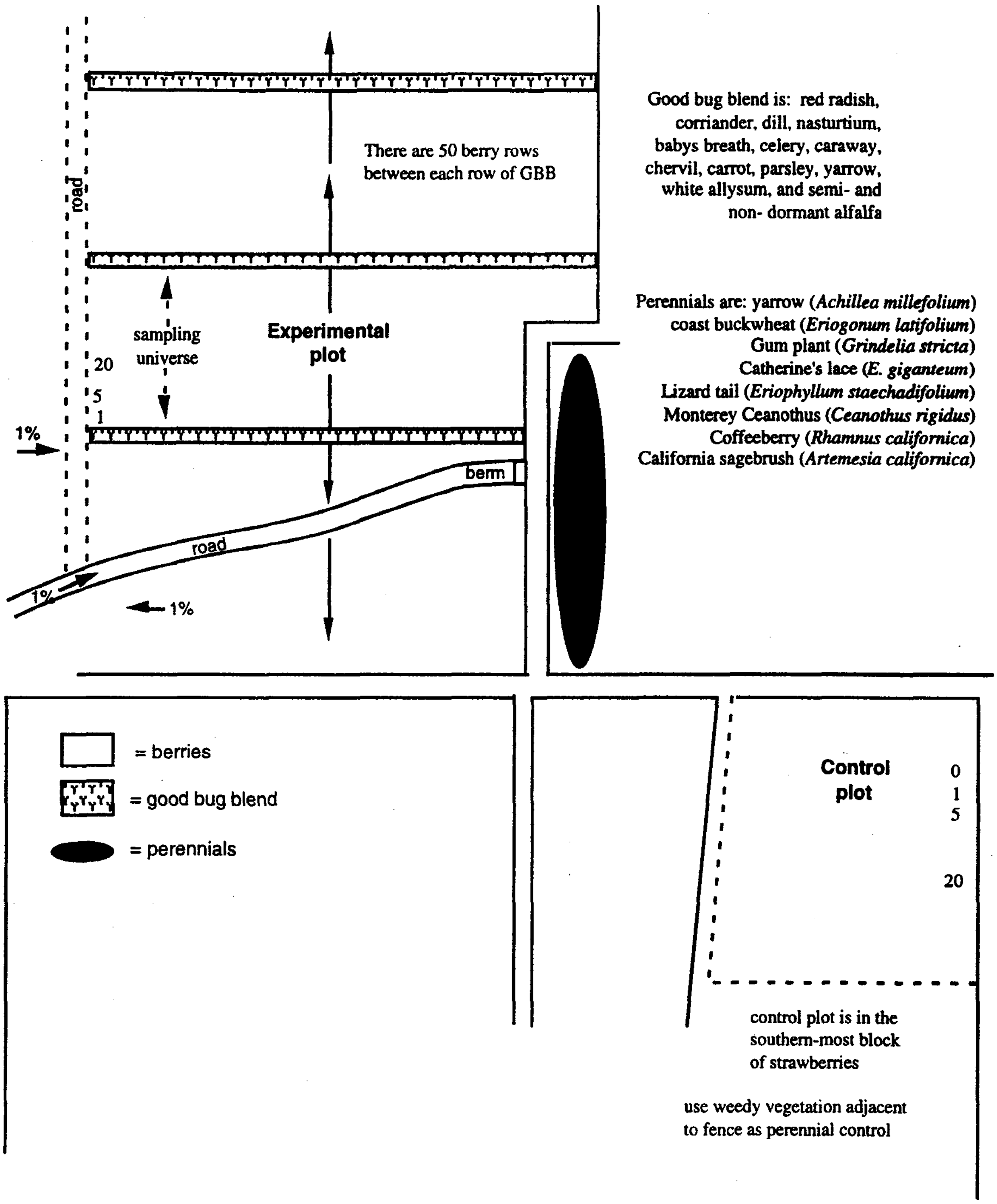
= berries

= good bug blend

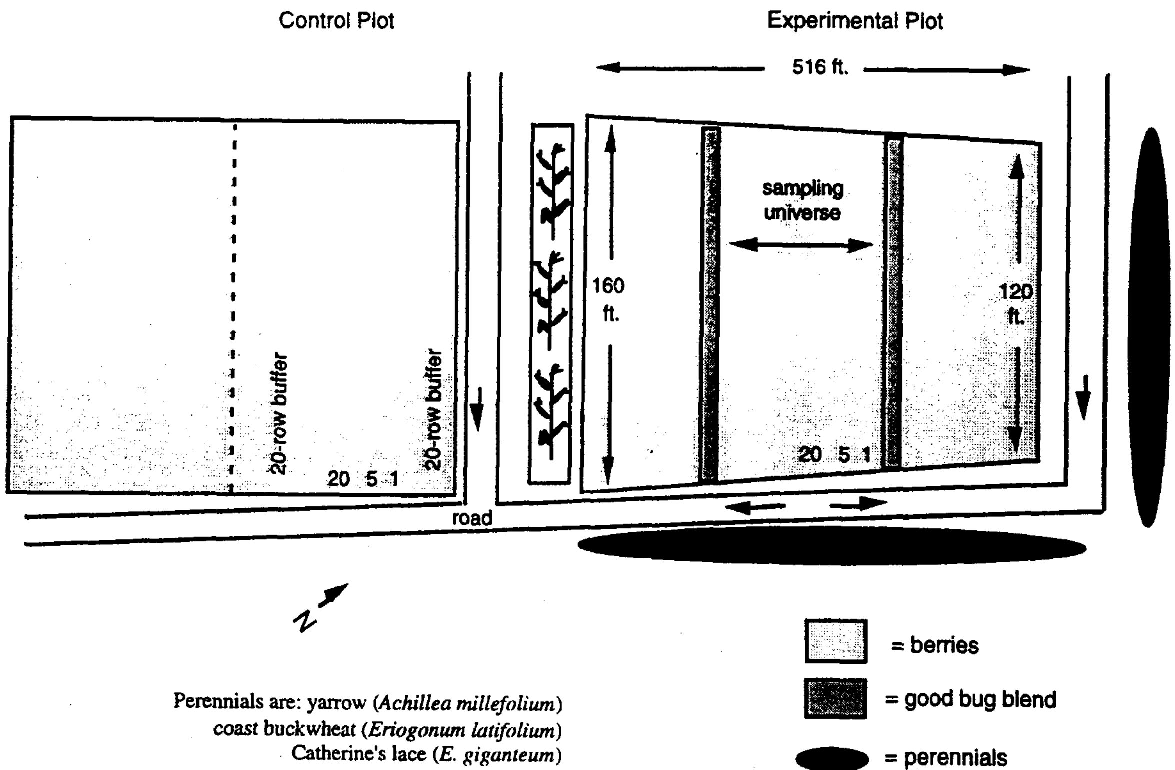
= native, perennial border

Good bug blend is: red radish, corriander, dill, nasturtium, babys breath, celery, caraway, chervil, carrot, parsley, yarrow, white allysum, and semi- and non- dormant alfalfa

Strawberry Farmscaping Project
Site Design: Coastal Prairie Habitat



Strawberry Farmscaping Project Site
Design - Oak Woodland Habitat



Perennials are: yarrow (*Achillea millefolium*)
coast buckwheat (*Eriogonum latifolium*)
Catherine's lace (*E. giganteum*)
'Blue Blossom' Ceanothus (*C. thrysifloris*,
Ceanothus cuneatus
Coffeeberry (*Rhamnus californica*)
California sagebrush (*Artemesia californica*)
Mock heather (*Haplopappus ericoides*)
Blue elderberry (*Sambucus mexicana*)

Good bug blend is: red radish, corriander, dill, nasturtium, babys breath, celery, caraway, chervil, carrot, parsley, yarrow, white allysum, andsemi- and non- dormant alfalfa